

- III. "The Influence of Stress and Strain on the Physical Properties of Matter. Part III. Magnetic Induction (*continued*). The Internal Friction of Iron, Nickel, and Cobalt, studied by Means of Magnetic Cycles of very minute Range."*
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(Abstract.)

The author has already studied the internal friction of metals by the method of torsional oscillations, and deduced certain simple laws relating thereto. One of the principal objects of the present enquiry was to ascertain how far the dissipation of energy resulting from statical molecular friction which occurs in magnetic cycles of very minute range would be amenable to the laws of dissipation of energy occurring in torsional cycles. The "ballistic" method of observation has been employed, the arrangements being exceedingly sensitive so as to admit of the use of very feeble magnetising forces.

The following is a summary of the results obtained :—

1. When a rod of iron, nickel, or cobalt is made to pass through a complete magnetic cycle of sufficiently minute range of magnetising force, the changes of magnetic induction can be expressed by an equation of the form—

$$y = Ax + Bx^2,$$

where x represents the change of magnetising force as the force passes from its greatest value in the cycle to zero, if the force be always applied in the same direction, or as the force passes from its greatest value in the one direction to its greatest value in the opposite direction, if the force be alternately applied in one direction and in the opposite, y represents the corresponding change of magnetic induction, and A and B are constants throughout the cycle.

2. The values of A and B are the same for magnetic cycles of different ranges of magnetising force, provided the force does not exceed certain limits. These limits vary considerably with the nature of the metal and with the mechanical or thermal treatment to which it may have been subjected.

3. The constant A is a measure of the magnetic permeability of the metal when the magnetising force is infinitesimal. The product of B and the cube of the maximum force in the cycle is a measure of

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the dissipation of energy, arising from statical friction among the molecules, in the performance of the cycle.

4. The internal friction of iron, nickel, and cobalt in any complete cycle may be decreased by repetition of the cycle; the molecules are said to be "accommodated" by this process.

5. The molecular "accommodation" of freshly-annealed iron can be largely aided by repeatedly raising the metal to 100° C. and then allowing it to cool.

6. The "accommodation" of the molecules of iron, nickel, and cobalt is disturbed by very slight mechanical shocks, by small change of temperature, or by magnetisation beyond certain limits; under such influences the internal friction may for a time, or even permanently, be considerably increased.

7. The values of A and B for iron, nickel, and cobalt can be very largely decreased by permanent mechanical strain. They may also be largely decreased in the case of steel by sudden cooling from a high temperature. No amount of strain, however, whether produced by mechanical or thermal agency, can reduce either the magnetic permeability or the internal friction below certain limits.

8. The values of A and B for iron are temporarily increased by loading not carried beyond a certain limit; beyond this limit both A and B decrease with increase of load.

9. The values of A and B for iron, nickel, and cobalt are temporarily increased when the temperature is raised from 0° C. to 100° C.

The amount of increase is much greater in freshly-annealed iron wire than in the same wire after it has been repeatedly raised to 100° C. and then cooled.

10. In both torsional and magnetic cycles of sufficiently minute range, the dissipation of energy from internal friction is independent of the *rate* at which the cycle is performed.

11. In both torsional and magnetic cycles of given range of force the average dissipation of energy per cubic centimetre does not depend upon the *dimensions*, provided that in magnetic cycles the length is sufficiently great to permit of neglecting the effect of the ends.

12. It follows from 3 that the dissipation of energy in a *magnetic* cycle is proportional to the *cube* of the maximum magnetising force in the cycle. On the contrary, the dissipation of energy in a *torsional* cycle is proportional to the *square* of the maximum torsional force provided the force does not exceed certain limits.

13. As regards "accommodating" influences and also as regards those influences which disturb "accommodation," the dissipation of energy in a magnetic cycle seems to be strictly analogous to the dissipation of energy in a torsional cycle. But the temporary and permanent effects of mechanical stress and the temporary effects of change of temperature are very different in the two kinds of cycles.